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EFFECT OF SEVERE RAINSTORMS ON INSLOPED AND OUTSLOPED ROADS

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ABSTRACT

Three heavy rainstorms that produced from about 7.5 to 10.0 inches of rain in central Idaho in a 10-day period in October 1962, caused considerable damage to newly constructed logging roads. Insloping a roadbed under the time, topographic, soil, and storm conditions described is more desirable than outsloping as a measure for preventing erosion and damage to the roads.

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INTRODUCTION

In central Idaho forests of the Intermountain Region, secondary or infrequently used logging roads are "put-to-bed" after completion of timber harvest operations as prescribed by Forest Service policy. This treatment usually involves (a) removing all temporary culverts, (b) outsloping the road surface and removing berms, (c) installing earthen cross drains at proper intervals, and (d) seeding the road surface, cut banks, and fill slopes. An empirical guide for proper spacing of cross drains has been developed and published.² Soil stability has been improved by using these erosion control measures on roads constructed on moderate to steeply sloping terrain.³

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² Haupt, H. F. A method for controlling sediment from logging roads. U.S. Forest Serv. Intermountain Forest and Range Expt. Sta. Misc. Pub. 22, 22 pp. 1959.

³ Haupt, H. F., and W. J. Kidd, Jr. Effects of logging disturbance on sediment production from a virgin ponderosa pine forest. 1963. (In preparation, Intermountain Forest and Range Experiment Station.)

Preventing erosion on soils derived from granite becomes more critical and difficult as logging is extended from moderate slopes to more rugged terrain where slope gradients often exceed 60 percent. Here, roadbeds must be partially or entirely "benched" on rock that requires deep cuts and consequently produces a surplus of road material. This material is usually castover and comes to rest in long unstable fills that may extend for 100 feet or more down a ravine on the "incurve" section of a road. These fills are generally shorter on the side slope below the "outcurve" section.

In recent years, land managers have questioned the erosion-prevention practice of draining these precariously situated roads by outsloping and removing berms, and then installing earthen cross drains on incurves, particularly at intersections with swales. An alternative--that the roadbed be insloped and water prevented from flowing onto the fill except at selected points--has been advocated.

THE STUDY

Both concepts of road drainage were evaluated on a newly built, secondary logging road on the Zena Creek logging study, Payette National Forest. The road, constructed in June 1962, traverses a steep mountain slope with gradients generally exceeding 60 percent. The slope is broken by numerous ravines and swales, and its general aspects are west and southwest.

The shallow, very coarse sandy soils above the road were categorized into three major soil units, Nos. 2, 8, and 3.⁴ Soil unit No. 2 varies in depth to bedrock from 6 to 20 inches and occupies the ridges and side slopes; unit No. 8 may be as deep as 48 inches and characteristically occupies the swales; unit No. 3 contains granite rock outcropping amounting to 10 to 25 percent areawise. The soil of the latter unit, usually less than 12 inches deep, overlies relatively hard granite bedrock and usually occurs on slopes greater than 70 percent. Vegetation consists mainly of sparsely stocked ponderosa pine with little or no understory.

The postlogging treatment applied to portions of the road included outsloping with frequent earthen cross drains spaced from 30 to 90 feet apart. The angle of outsloping was staked to a minimum of 5 percent or equal to the road gradient if greater than 5 percent, but not exceeding the maximum road gradient measured, which was 7 percent. The same treatment was applied to the insloped sections of road, except that on the insloped road some earthen cross drains were eliminated on incurves opposite swales. Insloping refers to uniform sloping of the road from outside to inside with no inside ditch.

⁴ Olson, O. C. Soils of the Zena Creek Logging Study, Payette National Forest, Region 4. 1960. (Unpublished soils report on file at Intermountain Region, U.S. Forest Service, Ogden, Utah.)

Culverts were installed "on original water grade" in major ravines and the road-bed for about 300 feet immediately above was insloped to drain water to the culvert. This practice of installing culverts was applied to both the outsloped and insloped sections of the road.

Finally, the road shoulders and fill slopes were seeded with a grass mixture in September and covered with chopped hay and asphalt binder (fig. 1-A). A short section of fill slope along the insloped road was reserved for plots on which to study methods of establishing plant cover.



Figure 1.--Outsloped section of study road, cross ditched and mulched: A, prior to the October 1962 rainstorms; B, following the October 1962 storms.



RAINSTORM HISTORY

September 1 to October 5.--From September 1 to October 5, 1962, rainfall in the vicinity of the study road, situated approximately one-half mile between the Deep Creek and Secesh Camp rain gage stations, was estimated at 1.25 inches. Most of it fell sporadically and evaporated shortly after falling. Therefore, at the advent of the October 6 to 15 rainstorms the soil mantle was essentially dry.

October 6 to 15.--Three low intensity rainstorms of 8-, 38-, and 87-hour duration, occurred in rapid succession within a period of 10 days in the Zena Creek logging study area. Rainfall produced by these storms was measured in four recording gages. Total rainfall varied from 7.60 inches to 9.99 inches (table 1). Intensity of the rainfall did not exceed 0.48 inch per hour for any 10-minute period nor 0.20 inch for any given hour.

Table 1.--Rainfall at five rain gage stations in central Idaho for
October 6 to 15, 1962

Date	Zena Creek area rain gage stations ¹				
	Circle End Creek	Oompaul Creek	Deep Creek	Secesh Camp	McCall station ²
	Elev. 4,100'	Elev. 5,000'	Elev. 5,060'	Elev. 4,220'	Elev. 5,020'
	- - - - - Inches - - - - -				
6	0.03	0.00	0.02	0.00	0.00
7	.58	.63	.37	.64	.06
8	.28	.34	.33	.30	.38
9	1.67	1.66	1.20	1.29	.58
10	1.45	1.30	1.45	1.51	1.03
11	1.27	1.40	1.19	1.07	.30
12	1.33	1.32	1.10	1.14	1.83
13	1.40	1.36	.86	1.05	³ .70
14	.43	1.83	1.01	1.04	³ 1.25
15	.02	.15	.07	.05	.32
Total	8.46	9.99	7.60	8.09	6.45

¹ Recording gages.

² Nonrecording gage.

³ Included a trace of snowfall.

To determine whether this rainfall established a record high, storm characteristics for the same period were examined at the nearest U.S. Weather Bureau station in McCall, Idaho, located 21 miles southwest of the study area (table 1). This station started in 1905 and has been operated continuously except from 1910 to 1916. Records indicated that the 8 consecutive days of rain in October 1962 were the wettest in the history of record.⁵ By inference, the storms which struck the study area road were unprecedented relative to total rainfall.

Precipitation from the October storms produced in a few days a condition that normally develops over a period of several months on watersheds having shallow soils. During a usual autumn, rains partially recharge the soil mantle; this process continues through late winter as the snowpack melts. By early spring, seepage flow commences and streams begin to rise slowly. Unlike the usual spring runoff, a tremendous surge of seepage flow that caused high peaks in local streams was generated by the steady rainfall that occurred during the third storm, whose duration was 87 hours.

The most recent storm period in central Idaho having similar characteristics was December 18 to 23, 1955.⁶ The record-breaking rain-on-snow floods of that period were more widespread but were generated by less rainfall than that during the period October 6 to 15, 1962; however, the McCall weather data show that the 1955 event was preceded by considerable antecedent rain and snow. As a result, streamflow peaks reached higher levels than in October 1962.

SEEPAGE FLOW, CHANNEL FLOW, SLOUGH, AND EROSION ON THE SECONDARY LOGGING ROAD

The thin, porous soil mantle above the road being studied was saturated early in the storm period. Because these soils have rapid internal drainage,⁷ undoubtedly a substantial portion of the 7 to 9 inches or more of rainfall moved through the soil and over the bedrock as subsurface flow. No evidence was found of overland flow having originated on the surface of the forest floor. Swales, heretofore dry, produced channel flow or emitted subsurface flow directly at the face of the road cut bank. Two days after the last storm, water was observed dripping from beneath the very shallow mantle in contact with unfractured bedrock. A few swales continued to produce seepage flow for 3 rainless weeks following the storms.

⁵U.S. Weather Bureau. McCall, Idaho weather station original field forms (archives), Municipal Airport, Boise, Idaho. 1906. (Data on file at the State Archives, Municipal Airport, Boise, Idaho, U.S. Weather Bureau.)

⁶U.S. Weather Bureau. Climatological data, Idaho 58(12): 156-157. 1955.

⁷See footnote 4, page 2.

The road profile, having been subjected to almost steady rainfall for about 10 days and to channel-derived and subsurface flows, became saturated, and large expanses of the fill portion of the road prism slumped and eroded, irrespective of the mechanical systems of drainage applied. Surprisingly, culverts functioned without plugging. Vertical displacement of soil was generally confined to the fill slope, which at some places inclined 90 percent. Laboratory analyses revealed that the clay or aggregating constituent of fill material was less than 4 percent by weight.⁸

DAMAGE TO OUTSLOPED ROAD

Where the road was outsloped, damage from erosion and slough decreased the usable width of roadbeds. Greatest damage occurred at the mouth of swales on the incurve (fig. 2). This was caused by the concentration of subsurface flow as well as by surface flow at these points along the road. An incurve usually has a higher proportion of fill material to solid bench; therefore it is inherently more unstable when saturated.

All outlets of earthen cross drains were deeply eroded. Observations along the road where surface water spilled over the edge, other than at a cross drain, indicated that further wetting caused slough and erosion on the fill slope proper (fig. 1-B). Particularly on an incurve, surface and seepage flows were literally funneled onto the fill material and caused severe damage. Mud-rock flows, set in motion on the fill, moved several hundred feet further down the ravine. One flow moved 850 feet downslope to a lower road.

⁸U.S. Forest Service. Soil stabilization project, Intermountain Forest and Range Experiment Station. 1962. (Data on file at the Boise, Idaho field office of the Intermountain Forest and Range Experiment Station, U.S. Forest Service.)



Figure 2.--Outsloped section of study road opposite slight swales. Note wet dark soil on cut bank caused by seepage.

DAMAGE TO INSLOPED ROAD

Damage to the bed of the insloped road from erosive cutting was slight. The lateral flow of water confined to the inside of the roadway was incapable of cutting into the solid bench of the road. Although slough from the cut bank above could have blocked the flow of water, it was negligible on this road because of the predominance of exposed rock and shallowness of soils (fig. 3). Blocking of inside drainage by accumulated slough has often been postulated as a disadvantage of insloping.

Surface water overtopped the angle of the inslope only where it was diverted from the roadbed by an earthen cross drain. At those points erosion damage to the fill even on an outcurve was severe because of the large volume of storm runoff. However, the undisturbed side slope below an outcurve tended to absorb the storm runoff and slowed the movement of sediment flows before they reached a ravine or stream. Past observations on similar soils on the Boise National Forest showed that side slope obstructions such as brush, logging slash, rocks, standing trees, and stumps effectively retarded sediment flows.⁹

Damage to the fill of the insloped road, other than at an earthen cross drain, although fairly widespread, was less serious than on the outsloped road. Considerable slumping below the edge of the roadbed resulted from the intercepted rainfall and subsurface flow. The effect of subsurface flow in causing slumping was very pronounced where the road crossed a swale. Quite by accident, it was possible to isolate and observe this relative effect on the section of road set aside for plot studies. Steel plot frames located on the fill slope on the incurves were displaced downhill or obliterated

⁹ Haupt, H. F. Road and slope characteristics affecting sediment movement from logging roads. Jour. Forestry 57: 329-332, illus. 1959.

Figure 3.--Insloped section of road with low berm, following the October 1962 storms. The inside of the road is relatively free of slough.



by intensive slumping; those installed on the outcurves were displaced only slightly because of minor slumping (fig. 4). These observations further point up the vulnerability of the fill portion of incurves.

IMPLICATIONS

Two erosion prevention practices, insloping and outsloping, were evaluated on a secondary logging road that (a) had been in existence less than 6 months, (b) traversed a steep mountain with slopes generally exceeding 60-percent gradient, and (c) left exposed, in most instances, an 8- to 14-foot cut bank of granite rock overlain by a shallow soil, generally less than 20 inches deep.

Observations indicate that insloping a roadbed of the type described above, before this severe long-duration rainstorm, is more desirable than outsloping as a measure for preventing erosion. Specifically, the inslope should be designed to lead as much storm runoff as possible away from the long fill on the incurve of the road. Where culverts are to be used in major ravines, they should be located on the original water grade so that they do not discharge on the fill of the incurve but drain into the original channel. Where earthen cross drains are to be used, they should be located to discharge their flows on the outcurve of the road. Below the outcurve the undisturbed side slope will tend to absorb road drainage and retard sediment flows before they reach a ravine or stream.

Even with the best design of road drainage, erosion damage may be expected following as heavy rainfall as occurred between October 6 and 15, 1962.



Figure 4.--Appearance of an insloped section of road set aside for plot studies following the October 1962 storms. Arrows locate plot frames displaced from original position on incurves. Other plot frames remain nearly intact on outcurves.